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INFRARED RADIATION MEASUREMENTS OF COMBUSTION GASES

by

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INTRODUCTION

Knowledge of the infrared radiative properties of rocket exhaust gases is required in many applications. Examples include the prediction of radiative heating to the base regions of multi-engine vehicles and the long-range detection of ballistic missiles. The magnitude and characteristics of this infrared radiation depends on the flame composition and temperature.

Analytical studies of the radiative heating from rocket exhaust plumes indicated the need for complete and accurate spectral absorption data. Although numerous investigations of CO_2 and H_2O have been reported recently, the results are for a maximum temperature of 2000 ^{o}F or are restricted to a narrow wavelength region. Furthermore, existing theories for predicting infrared radiation from high temperature gases are based on highly idealized physical models. The validity and applicability of the results predicted from these theories require experimental confirmation.

The objective of the present study is to obtain the spectral characteristics of a number of common combustion products under a variety of accurately known thermodynamics and optical conditions. Considerations leading to the design and fabrication of an experimental apparatus for this purpose are given in reference 1. This equipment consists of a graphite resistance furnace with an inert ceramic tube liner for the containment of high-temperature gases, and an optical system for detection of the infrared absorption. The test optical path is limited to the central zone of the furnace by the use of window holders at each end. Hot-pressed zinc selenide windows were originally employed because this material is transparent in the 1-20 μ wavelength region and inert to H_2O, CO_2 and CO up to a temperature of 540° F. In order to keep these windows below this limit it was necessary to water cool the holders in which they were mounted.

Data for the fundamental band of CO at temperatures of 300° K and 1800° K and at pressures from 0.25 to 3.0 atmospheres obtained with this system were reported in reference 1. Although agreement with existing results was within 15 percent, the substantial temperature variation along the test optical path caused by the water-cooling of the windows made the comparison open to some question. Because of this the water-cooled window holders were replaced with alumina tubes and sapphire used for the windows in place of zinc selenide.

Spectral absorption measurements of CO up to 1200° K were made with these modifications. The pressure was varied from 0.5 to 3 atmospheres and the optical path length from 5 to 20 centimeters. Spectral and total band absorptivities determined from these measurements were presented in the last quarterly progress report.[2]

At temperatures above 1200° K, the glass frit used to mount the sapphire windows in the alumina tubes weakened and permitted gas leakage to occur. Nitrogen-cooled stainless steel window holders were therefore fabricated. Sapphire windows were held in these by means of inside threads and a ring-shaped nut. Sealing of the windows in the holders was accomplished with a platinum O-ring.

SPECTRAL ABSORPTIVITY DATA FOR CO AT 1500° K

Spectral absorption measurements of the CO fundamental band at 1500°K have been obtained with the new stainless steel window holders. The pressure was varied from 0.5 to 3 atmospheres and the optical path length from 5 to 20 centimeters: the results for path lengths of 5 and 10 centimeters are presented in Figures 1 and 2. For comparison with prior data for 10 centimeters and a temperature of 1200° K is included in Figure 3.

In order to assess the amount of temperature variation along the test path a thermocouple was mounted at the end of one of the stainless steel holders. Its location was approximately 1.5 centimeters closer than the sapphire window to the center of the furnace. The reading of this thermocouple was about 5 per cent lower than the temperature at the center of the furnace as measured with an optical pyrometer. In order to obtain an average temperature of 1500° K the data were therefore taken with the center temperature held about 5 per cent above 1500° K.

As the temperature is increased the changes to be expected are a reduction in the maximum absorptivities and a shifting of the wave members at which the maximums occur. In general the results obtained bear this out. However the magnitudes of the changes appear to be dependent on the pressure level. The possibility of correlating these effects on a total band absorption basis is being investigated.

PROJECT SCHEDULE

On the basis of operation at an average temperature of 1500° K it has been estimated that the stainless steel holders with sapphire windows can be used up to an average temperature of 1800° K. It is therefore planned to obtain fundamental and first overtone spectral absorptivity measurements with CO at 1800° K. Upon completing this a report on all CO spectral measurement will be prepared. This will include correlation of spectral data at a fixed temperature and a method of correlating total band absortivity with temperature.

REFERENCES

1. W. H. Giedt, C. L. Tien and others, "The Study of Base Heating by Radiation from Exhaust Gases," Final Report, Contract No. NAS 8-850, NASA, Institute of Engineering Research, University of California, Berkeley, California (1964).

2. M. M. Abu-Romia, L. S. Wang, W. H. Giedt, and C. L. Tien, "Infrared Radiation Measurements of Combustion Gases," Third Quarterly Progress Report, Contract No. NAS 8-850, NASA, Institute of Engineering Research, University of California, Berkeley, California, April, 1965.

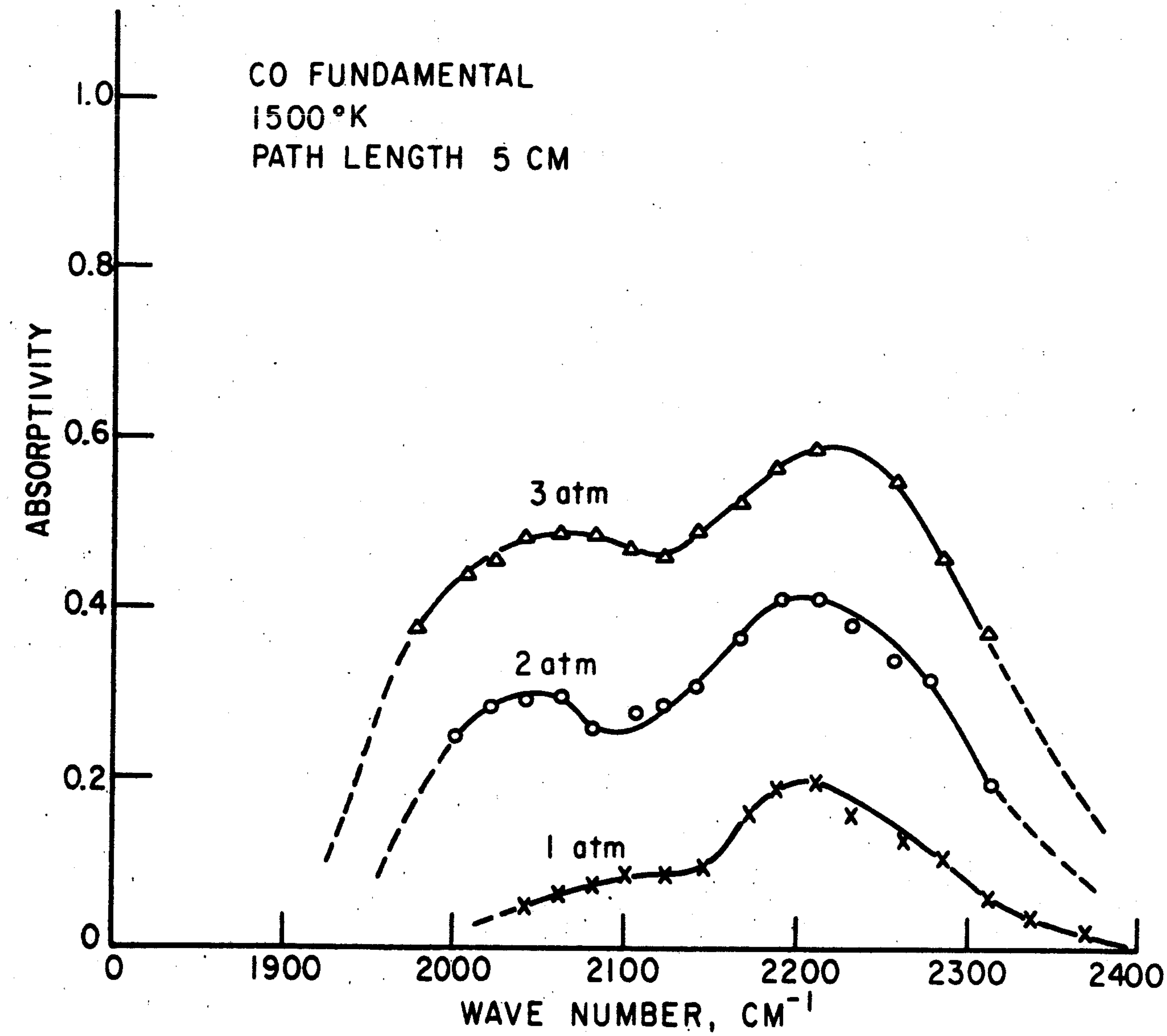

FIG. 1 SPECTRAL ABSORPTIVITY OF FUNDAMENTAL BAND OF CO GAS AT TEMPERATURE 1500 °K AND AT PATH LENGTH 5 CM

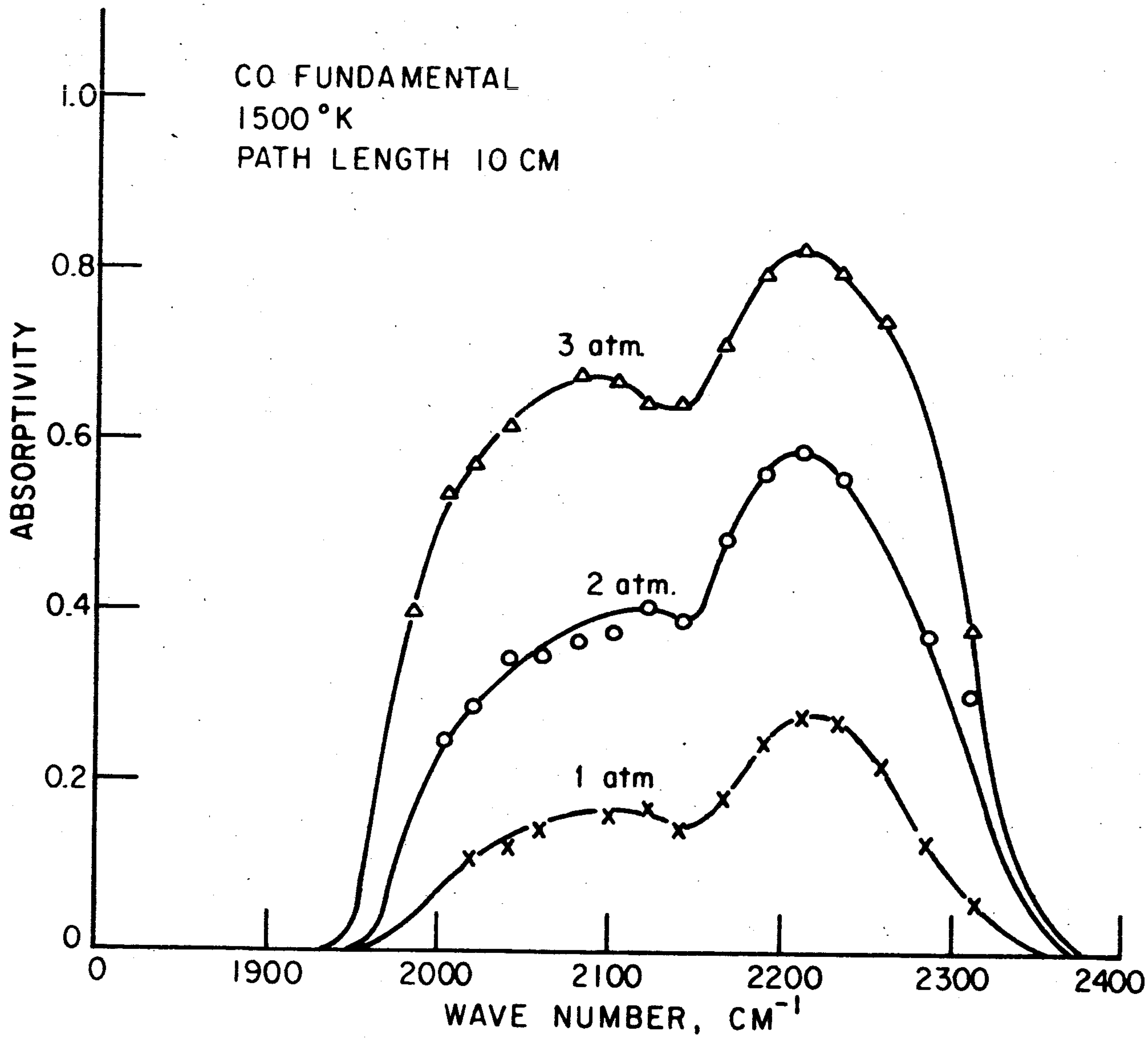

FIG. 2 SPECTRAL ABSORPTIVITY OF FUNDAMENTAL BAND OF CO GAS AT TEMPERATURE 1500 °K AND AT PATH LENGTH 10 CM

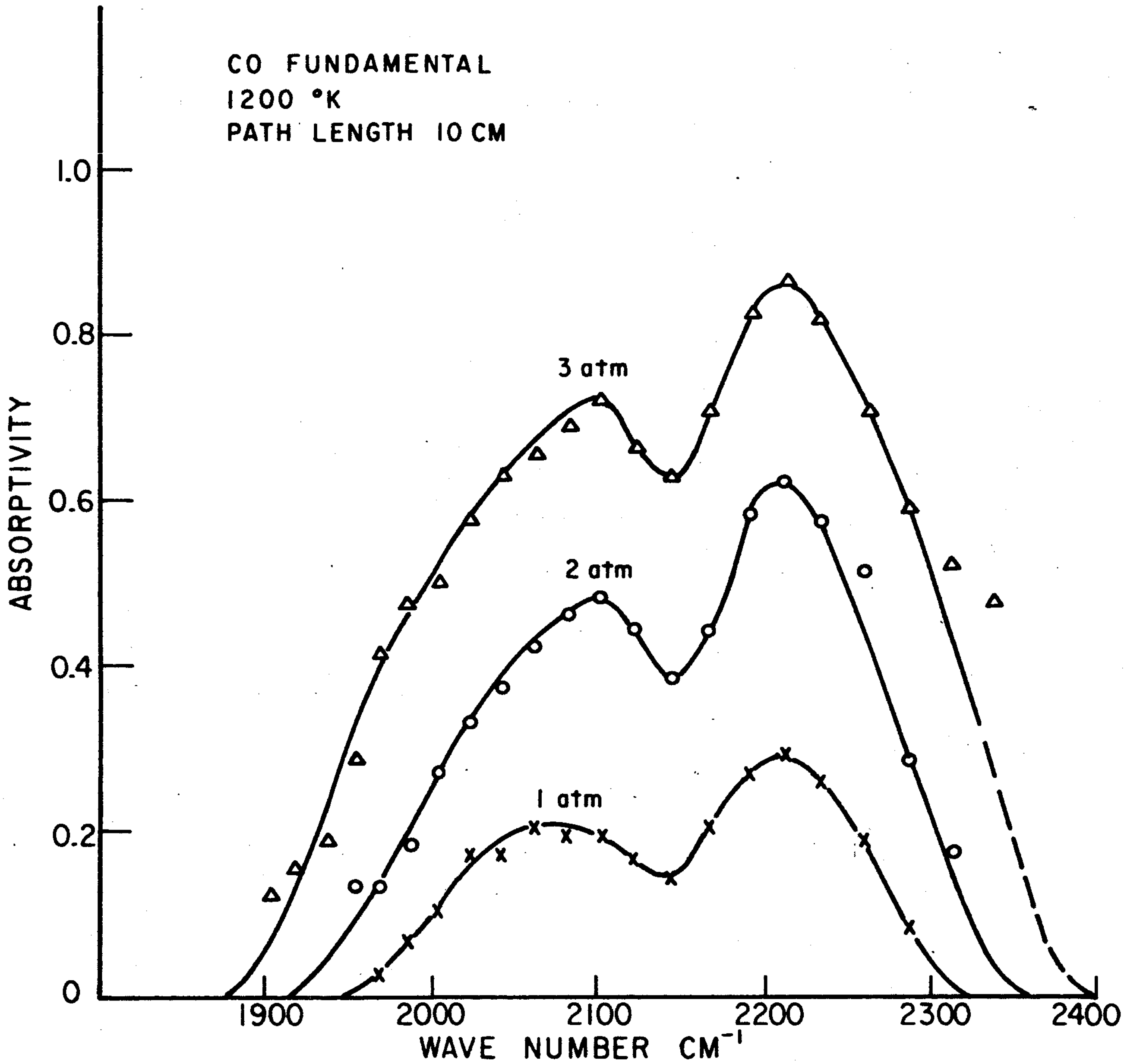

FIG. 3 SPECTRAL ABSORPTIVITY OF FUNDAMENTAL BAND OF CO GAS AT TEMPERATURE 1200 °K AND AT PATH LENGTH 10 CM